11-12. Two Astronomical Tables from the Tebtunis Temple Library

The fragments edited below were discovered in 1931 among the large stash of Egyptian and Greek papyrus manuscripts from the Roman period now known as the Tebtunis Temple Library[1]. Previously, six other Greek astronomical tables certainly originating from Tebtunis (some of them definitely from the Temple Library) and about the same number very probably from Tebtunis have come to light[2]. Like the much more numerous astronomical tables from Oxyrhynchus, they were presumably intended to provide astronomical data for the practice of astrology[3].

Following the pattern of the Oxyrhynchus material as well as of the entire corpus of known astronomical tables on papyri, the tables from Tebtunis divide into two groups: a larger number of almanac-style tables containing precomputed positions of heavenly bodies for a series of dates at fairly close intervals, and a smaller number of more theoretically oriented tables, demanding some mathematical facility on the part of their users, that were the primary tools for computing the positions and phenomena recorded in almanacs and horoscopes[4]. The manuscripts from the Temple Library also include fragments of numerous astrological handbooks written in Demotic, but only two Demotic astronomical tables useful for astrology[5]; so it would seem that in Tebtunis the computational aspect of astrology was normally carried out using Greek resources (acquired from elsewhere?) but the interpretative aspect in Egyptian.

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[1] K. Ryholt, *On the Content and Nature of the Tebtunis Temple Library*, in *Tebtynis und Soknopaiu Nesos. Leben im römerzeitlichen Fajum*, S. Lippert - M. Schentuleit (edd.), Wiesbaden 2005, pp. 141-163. The P.Carlsberg 77 fragments were purchased, but certainly derive from clandestine excavations at the same spot and around the same time.

[2] See the papyri listed in M. Perale - A. Jones, *Greek Astronomical Tables in the Carlsberg Collection* (forthcoming), note 1, and P.Carlsberg 104, 141, 673, and 726 published in that article.

[3] A. Jones, *The Astrologers of Oxyrhynchus and their Astronomy* in *Oxyrhynchus: A City and its Texts*, A.K. Bowman - R.A. Coles - N. Gonis - D. Obbink - P. J. Parsons (edd.), London 2007, pp. 307-314.

[4] A. Jones, *A Classification of Astronomical Tables on Papyrus*, in *Ancient Astronomy and Celestial Divination*, N.M. Swerdlow (ed.), Cambridge (Ma) 1999, pp. 299-340.

[5] A. Winkler, *On the Astrological Papyri from the Tebtunis Temple Library*, in *Actes du IX^e^ congrès international des études démotiques, Paris 31 août - 3 septembre 2005*, G. Widmer - D. Devauchelle (edd.), Le Caire 2009, pp. 361-375. The Demotic astronomical tables are P.Carlsberg 31 and 32 (respectively table of eclipse possibilities and template of daily positions of Mercury), on which see Ryholt, *On the Content*, cit. at note 1, p. 153, note 58, where it is suggested that the two papyri may derive from a single roll. P.Carlsberg 9 is calendrical rather than astrological in purpose.

11. PSI inv. D 93 (Tavola)

The astronomical table on this single fragment (height 6.0 cm, width 3.5 cm) is written along the fibres, with no ruled tabular framework but horizontal rulings in black ink to separate sections of the table. On the verso are traces of writing, too abraded for us even to be able to identify the script. The hand of the table is a neat semicursive of the second century, bearing a general resemblance to P. Oxy. LII 3653 (Hypotheses to Sophocles, II century) and LVII 3992 (Letter of Aelius Theon to Herminus, II century). The hand of XLIII 3088 (Letter of a Prefect, 128 A.D. or later), though more cursively written, is also similar in many letter-forms: see in particular α δ ε η κ.

Text and translation

	] ̣		] x
	———		———
	] α γ		] 1 3
	———		———
	] α η		] 1 8
	] κα ζ		] 21 7
	] ιη η		] 18 8
	] ι̣ε θ		] 15 9
	———		———
	] α α		] 1 1
]	- κδ β	]	- 24 2
]	β κε γ	]	2 25 3
]β̣	δ ς δ	]2	4 6 4
]—	ε ς ε	]—	5 6 5
] ̣[ ]	ς κβ ς	]x[ ]	6 22 6
] ̣	ζ κη ζ	]x	7 28 7
]	θ̣ ιζ η	]	9 17 8

Comment

This is a fragment of a sign-entry almanac, the most frequently attested format of planetary almanac among papyrus tables from the late first century B.C. to the end of the fourth century A.D.[6]. The almanac lists computed dates of entry into zodiacal signs

[6] Jones, *A Classification*, cit. at note 4, pp. 324-325.

for the five planets (in the standard order Saturn, Jupiter, Mars, Venus, Mercury) for a succession of Egyptian calendar years, either according to the reformed Egyptian civil calendar or, less frequently, according to the unreformed calendar. Each line normally consists of three numbers, representing the ordinal number of the calendar month (counting from Thoth = 1), the day of the month, and the ordinal number of the zodiacal sign that the planet enters on that date (counting from Virgo = 1). However, in line 8 a horizontal mark located in the first position probably performs the same function of a modern ditto, indicating that the calendar month number is the same as in line 7, the first sign-entry into Mars. The first line in a planetary section often gives the zodiacal sign occupied by the planet on Thoth 1, regardless of whether this is a date of sign-entry.

The present papyrus preserves the sections for Saturn and Jupiter (lacking the month numbers) and most of the section for Mars for a single year, which was presumably identified in line 1. There are also a few traces of a preceding column along the left edge, likely the almanac for the preceding year. Although the dates of sign-entry in an almanac depend to some extent on the astronomical theory or set of tables that was employed to calculate them, in most cases one can establish the date of an almanac from which the year numbers are missing by comparing the data for several planets with recomputation either by modern astronomical theory or by Ptolemy's tables, which are the only ancient set of tables that survive complete. Consulting a reconstructed sign-entry almanac computed by Ptolemy's tables for the interval from the late first century B.C. through the end of the third century A.D., we found a good match with the papyrus for only one year, A.D. 101/102 = Trajan year 5, according to the unreformed Egyptian calendar[7]. The recomputed entries for this year are:

Trajan 5 (unreformed Egyptian calendar)

Saturn

1 1 3	in Scorpio
7 25 4	entry into Sagittarius
9 1 3	reentry into Scorpio (retrograde motion)

Jupiter

1 1 8	in Aries
3 28 7	reentry into Pisces (retrograde motion)
5 23 8	reentry into Aries
10 23 9	entry into Taurus

[7] The recomputed almanac was based on Ptolemy's *Handy Tables*, with an adjustment to the longitudes ("Theon's formula") to convert Ptolemy's tropical longitudes to the approximate sidereal frame of reference prevalent in this period; see A. Jones, *Ancient Rejection and Adoption of Ptolemy's Frame of Reference for Longitudes*, in *Ptolemy in Perspective: Use and Criticism of his Work from Antiquity to the Nineteenth Century*, A. Jones (ed.), New York 2010 (Archimedes 23), pp. 11-44.

Mars

1 1 1	in Virgo
1 8 2	entry into Libra
2 21 3	entry into Scorpio
4 2 4	entry into Sagittarius
5 11 5	entry into Capricorn
6 19 6	entry into Aquarius
7 28 7	entry into Pisces
9 7 8	entry into Aries
10 17 9	entry into Taurus
11 30 10	entry into Gemini

The most obvious discrepancy is that the recomputed almanac has Saturn entering Sagittarius briefly before moving back into Scorpio; but reducing the planet's longitudes by a mere quarter of a degree, which is insignificant in relation to the divergences among ancient planetary theories, would eliminate these sign entries. The missing month numbers for Jupiter in the papyrus were likely, though not certainly, the same as those of the corresponding sign-entries in the recomputed almanac. The agreement of dates for Mars is quite good except for the sign-entry into Libra (line 8), where the papyrus appears to have a scribal error since it is astronomically impossible to have two successive sign-entries in direct motion just 31 days apart.

12. PSI inv. D 92 + P.Carlsberg 77 (Tavola)

This manuscript consists of one fragment (height 14.2 cm, width 3.9 cm) in Florence and four (fr. 1: height 3.0 cm, width 2.0 cm; fr. 2: height 3.5 cm, width 2.0 cm; fr. 3: height 2.0 cm, width 1.0 cm; fr. 4: height 9.5 cm, width 3.5 cm; fr. 5: 5.0 cm, width 2.5 cm) in Copenhagen. The astronomical table is written across the fibres within a black ruled tabular framework. PSI inv. D 92 preserves 6 cm lower margin. P.Carlsberg 77 fragment 5, which has only tabular rulings without any other writing and is not transcribed below, may preserve 1.5 cm upper margin. All other sides of all the fragments are broken. On the recto, in a fine hand probably belonging to the Roman period, are fragments of a Demotic literary narrative concerning the legendary King Sesostris, similar to if not the same as the Sesostris narrative preserved in two other papyri from the Tebtunis Temple Library[8]. The hand of the table is a regular, upright, rounded capital, markedly bilinear, datable to the I-II century A.D.[9]. An overall impression of artificiality is garnered from the presence of connection strokes at mid-height, external to the shape of the letters (see ρ, λ at l. 4, η at l. 7). The chiaroscuro appears to be the result of a further intervention after the writing of individual letter shapes, rather than achieved through the variation of the pen inclination in the fluent process of writing. Particular attention is given to ornamental finials. The oblique of ν is occasionally lengthened to the left, to give an effect of continuity. The letter-shape recalls the writing of P. Berol. inv. 6926 + P. Gen. 2.85 (= Roberts, *GLH* 11a, *Novel of Ninus*, before 100/101 A.D.), with the exception of μ, here in two movements with rather flattened central element. Other remarkable features are big looped ρ, rounded α made in one sequence, broad-based β. The zero symbol is unusual: a horizontal stroke beginning on the left with a hook below the line, and ending on the right in an arc doubling backwards above the line and ending in a small loop. This appears to be a variant of the comparatively rare form of the zero having a dot or small circle *above* a horizontal stroke[10].

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[8] We thank Kim Ryholt, Ghislaine Widmer, Richard Jasnow, and Jacco Dieleman for examining the recto; on the related papyri, P.Carlsberg 411 and 412, see G. Widmer, *Pharaoh Maâ-Rê, Pharaoh Amenemhat and Sesostris: Three Figures from Egypt's Past as Seen in Sources of the Graeco-Roman Period*, in *Acts of the Seventh International Conference of Demotic Studies, Copenhagen, 23-27 August 1999*, K. Ryholt (ed.), Copenhagen 2002, esp. pp. 387-392. Kim Ryholt also notified us of the P.Carlsberg 77 fragments. A Greek astronomical text written on the back of a discarded Demotic papyrus is exceptional, but not unparalled. P.Carlsberg 239 verso (a publication of which by A. Jones and M. Perale will appear soon, see *infra* note 2) preserves a table of the Moon's mean longitude on the back of a Demotic account possibly from Socnopaiu Nesos.

[9] The authors wish to thank Daniela Colomo and Guido Bastianini for invaluable suggestions on the possible date of the hand of PSI inv. D 92.

[10] For forms of zero in astronomical papyri see A. Jones, *Astronomical Papyri from Oxyrhynchus*, Philadelphia 1999 (Memoirs of the American Philosophical Society 233), I, pp. 61-62.

Text and translation

PSI inv. D 92

ō] ọ̄	ρν̣α̣ [ιβ ō ō	0] 0	151 [12 0 0
ς̣] μ	ρ̣ν̣α̣ κ̣ [ιγ κ	6] 40	151 20 [13 20
κς] μō	ρν̣α̣ κ̣[η νγ κ	26] 40	151 2[8 53 20
ō] ō	ρνα λη̣ [ō ō	0] 0	151 38 [0 0
] μς μ	ρνα μ[ζ λγ κ	] 46 40	151 4[7 33 20
] μς μ	ρνα νζ̣ [λγ κ	] 46 40	151 57 [33 20
] ọ̄ ō	ρνβ η̣ [ō ō	] 0 0	152 8 [0 0
] κς μ	ρνβ ιη νγ̣ [κ	] 26 40	152 18 53 [20
] ς μ	ρνβ λ ι̣γ̣ κ̣	] 6 40	152 30 13 20
] ō ō	ρνβ μβ ọ̄ [ō	] 0 0	152 42 0 [0
] λ̣ ς μ	ρνβ μ̣δ ι̣[γ κ	] 30 6 40	152 44 1[3 20
] ̣ κς μ	ρνγ ς νγ [κ	]x 26 40	153 6 53 [20
] ̣ ō ō	ρνγ κ ō ō	]x 0 0	153 20 0 0

P.Carlsberg 77, fragment 1

] ̣γ̣ κ̣ [
] ̣γ κ̣ [
] ι̣β ọ̄ ō [
]δ̣ ι̣γ κ [
]ς νγ κ̣ [

] x3 20 [
] x3 20 [
] 12 0 0 [
]4 13 20[
]6 53 20 [

P.Carlsberg 77, fragment 2

]	σπ[
]	σπς [
]	σπζ [
]	σπη̣ [
] ọ̄	σπ[

]	28[x
]	286 [
]	287 [
]	288 [
] 0	28[x

P.Carlsberg 77, fragment 3

]	σ[
]	σ[
]	σ[

]	2[xx
]	2[xx
]	2[xx

P.Carlsberg 77, fragment 4

] . . [
] . . . .   [

]	τ̣ι̣ . [
] ọ̄	τι̣[
]ϛ μ	τι[
]γ̣ κ	τι[
] ō	τι[
]ϛ̣ μ	τιη [
] . κ̣	τιθ̣ [
] ọ̄ ō	τκ[
] μ	τκ[
] κ̣	τκ[
] ō	τ̣[
]ϛ μ	τ[
] κ	τκ̣[
]	τ̣[

] *illegible* [
] *illegible* [

]	31x [
] 0	31[x
]6 40	31[x
]3 20	31[x
] 0	31[x
]6 40	318 [
]x 40	319 [
] 0 0	32[x
] 40	32[x
] 20	32[x
] 0	3[xx
]6 40	3[xx
] 20	32[x
]	3[xx

Comment

In the best preserved fragment, PSI inv. D 92, we have parts of two columns of sexagesimal numerals. Of the left column, only the two lowest order fractional places are preserved (aside from traces of the preceding place in line 11 and perhaps 12 and 13); of the right, the whole number part and, in most lines, at least one fractional place. The left column displays a pattern of cycles of three lines, with two of them ending in x6,40 (such that x is apparently either 0, 20, or 40) and the third ends in 0,0. This is clearly an artifact of computation by an arithmetical algorithm, and further consideration shows that the cyclic pattern could not be the running total of a constant increment, but could be generated as a second-order arithmetical sequence, i.e. the running total of an increment that itself increases or decreases from line to line by a constant. To obtain a match with the preserved numerals, the constant, if an increment, must have ended in 13,20, or if a decrement, in 46,40. For example, making the provisional hypothesis that the numbers in the left column originally consisted of a whole number part followed by three fractional places, the following would be a possible reconstruction (with preserved digits in bold):

second difference	*first difference*	*tabulated number*
		0;36,0,0
	0;4,6,40	0;40,6,**40**
0;0,13,20	0;4,20,0	0;44,26,**40**
0;0,13,20	0;4,33,20	0;49,0,**0**
0;0,13,20	0;4,46,40	0;53,**46,40**
0;0,13,20	0;5,0,0	0;58,**46,40**
0;0,13,20	0;5,13,20	1;4,**0,0**
0;0,13,20	0;5,26,40	1;9,**26,40**
0;0,13,20	0;5,40,0	1;15,**6,40**
0;0,13,20	0;5,53,20	1;21,**0,0**
0;0,13,20	0;6,6,40	1;27,**6,40**
0;0,13,20	0;6,20,0	1;33,**26,40**
0;0,13,20	0;6,33,20	1;40,**0,0**

The numbers in the second column are gradually increasing. Despite the loss of most of the lower-order fractional places, we can estimate the mean increment between lines 6 and 13 as between 0;11,42 and 0;11,51. The numeral 44 in line 11 is almost certainly a scribal error for 54; with that correction all line-to-line differences are close to the average value. The increment is in fact increasing, since the difference between lines 12 and 13 is approximately 0;13,7 whereas between lines 6 and 8 it is less than 0;11. A bit of experimentation leads to a reconstruction of this column as another second-order arithmetical sequence with 0;26,40 as the constant second difference, as follows (well-preserved digits in bold, discrepant digit underlined):

second difference	*first difference*	*tabulated number*
		151;12,0,0
	0;8,13,20	151;20,13,20
0;0,26,40	0;8,40,0	**15**1;28,53,20
0;0,26,40	0;9,6,40	**151;3**8,0,0
0;0,26,40	0;9,33,20	**151;4**7,33,20
0;0,26,40	0;10,0,0	**151;57**,33,20

0;0,26,40	0;10,26,40	**152;8**,0,0
0;0,26,40	0;10,53,20	**152;18,5**3,20
0;0,26,40	0;11,20,0	**152;30**,13,20
0;0,26,40	0;11,46,40	**152;42**,0,0
0;0,26,40	0;12,13,20	**152;54**,13,20
0;0,26,40	0;12,40,0	**153;6,53**,20
0;0,26,40	0;13,6,40	**153;20,0,0**

The precise numerical parameters of the sequence are not completely determined by the preserved numerals, but our reconstruction is plausible given the evident arithmetical structure of the left column and the circumstance that the presumed second difference for the right column, 0;0,26,40, is exactly twice the smallest possible (and thus most probable) value for the second difference of the left column. Moreover, if we extrapolate the sequence backwards, we find that the first difference would be exactly 150;0,0,0 in the line that would be 30 lines above line 13; and this would be the sequence's minimum value since the first difference leading to the next line, 0;0,13,20, is less than the second difference so that one cannot extrapolate further backwards without assuming negative first differences. This coincidence of a minimum first difference with a round number in the running total is likely to be a deliberate element in the design of the table. Extrapolating forwards, we also find that the next round number arising in the running totals is 180;0,0,0 in the line that would be 60 lines below line 13, i.e. 90 lines below the apparent beginning of the sequence. The first difference in this line would be 0;39,46,40. We may suppose that this, too, was a deliberately chosen element. In other words, we propose that the sequence was intended to increase by exactly 30 units, from 150 to 180, in 90 constantly increasing increments beginning with zero, or with a value very close to zero.

It is easy to explain the parameters of the sequence as consequences of these hypothetical constraints. Let the constant second difference be s, and let the initial first difference d_0 be exactly zero. Then the nth first difference is

$$d_n = d_0 + ns$$

and the nth running total will be

$$t_n = t_0 + [n(n-1)/2]s$$

Hence for $n = 90$ and $t_n - t_0 = 30$,

$$s = 30/4005 \approx 0;0,26,57,59$$

Since this is arithmetically inconvenient, one may prefer to set $d_0 = s/2$, which is close to but not exactly zero, so that now

$$t_n = t_0 + [n^2/2]s$$

and for our chosen constraints,

$$s = 30/4050 = 0;0,26,40$$

$$d_0 = 0;0,13,20$$

$$d_{90} = 0;39,46,40$$

which are precisely the parameters we have proposed.

The most likely astronomical interpretation of such a sequence is as a planet's daily motion in longitude during the stage of its synodic cycle following its second stationary point. The round numbers delimiting the sequence further suggest that the table is not an ephemeris, that is, a list of actual longitudes during a specific year, but a template laying out a pattern of the planet's motion relative to an epoch position, which would be used along with a separate table of epoch dates and positions to enable the calculation of longitudes on arbitrary dates[11]. The fact that the second station is associated with a longitude (relative to epoch) of 150° shows that the planet cannot be Mercury, Jupiter, or Saturn, none of which traverse so many degrees in a synodic period.

The planet must in fact be Mars. In Fig. 1 (see Tavola ●), Mars's elongation from its longitude at second station is plotted over an interval of 90 days during a representative selection of synodic cycles during the first few years of the second century (the specific dates are not important). Because of the large eccentricity of Mars's orbit, there is a substantial variation in the planet's apparent speed, so that its progress over the 90 days following the station ranges from about 30° to nearly 40°. The reconstructed sequence of the papyrus represents well the slower extreme of the planet's behavior. It is possible that similar sequences were tabulated representing more rapid modes of the planet's synodic cycle, the choice of table being dependent on the planet's location in the zodiac.

Fig. 2 (see Tavola ●) plots a longer interval of Mars's longitudinal motion during part of the years A.D. 99-101 (from which "Cycle 1" in Fig. 1 was taken), beginning with conjunction and ending with the 90th day after second station; the Sun's motion is also shown, with a gray border approximating the range within which Mars would be too close to the Sun to be visible. A small circle marks the point at which Mars's longitude was 150° less than the longitude of its second station. It is clear that the starting point of the table, when the longitude relative to epoch was 0°, corresponded to Mars's first visibility.

We are unable to offer with any confidence an interpretation of the left column in PSI inv. D 92. In the absence of its higher-order digits we cannot even be sure of whether the tabulated quantity is increasing or decreasing and whether the trend is accelerating or decelerating. The pattern of endings of the sexagesimals shows that we are dealing again with a second-order arithmetical sequence but the constant second difference here must end in 13,20 (if additive) or 46,40 (if subtractive). Our best guess is that it contains either an earlier stage of the same sequence of positions of Mars, or a variant sequence applicable to the planet's motion in a different part of the zodiac.

P.Carlsberg 77 fr. 3 has part of a single column of numerals, preserving the lower order places. The sequence was a second-order arithmetical sequence with constant second difference ending in x0,26,40 (where x is any multiple of 10), very probably just 0;0,26,40 as in the sequence of PSI inv. D 92. If this was part of the same sequence,

[11] Jones, *A Classification*, cit. at note 4, pp. 311-314, and Jones, *Astronomical Papyri*, cit. at note 10, I, pp. 115-118.

there is precisely *one* place where it could belong, corresponding to days 71 through 75 counting from the day of second stationary point:

day	*elongation*
71	168;8,5**3,20**
72	168;40,1**3,20**
73	169;**12,0,0**
74	169;4**4,13,20**
75	170;1**6,53,20**

Fr. 2 preserves only a single trace of a numeral in the left column, and beginnings of numerals in the right column, which are in the range 280°-290° and, as the consecutive values 286, 287, 288 (with lost fractional parts) shows, increasing at a rate between half a degree and a degree and a half per day per row, which is consistent with Mars's speed when it is at an elongation of around 287° from its position at first visibility. Fr. 3 comes from not far above or below fr. 2, since there is continuity in the pattern of vertical fibers.

Fr. 4 again has the ends of the numerals in one column and the beginnings of the numerals in the next. The numerals in the right column are increasing within the range 310°-330°. The sequence of consecutive values 318, 319, and (presumably) 320, with lost fractional parts, again requires a rate of increase greater than half a degree per row and less than a degree and a half per row, consistent with Mars' rate of daily motion when it is at this elongation first visibility. The pattern of low-order sexagesimal digits in the left column is consistent with a constant rate of increase, with the constant increment (if additive) ending in x6,40, where x could be any multiple of ten.

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